SPECTROSCOPIC NOTES*

A NEW FORM OF SPECTROSCOPE

THE instrument, a description of which follows, was designed for attachment to the equatorial of 6·4in. aperture and 9ft. focal length, belonging to the observatory of Dartmouth College. It is especially intended for observations upon the solar spots and protuberances, and accordingly the principal object kept in view has been to combine a very high degree of power with compactness, lightness, facility of manipulation, and firmness of construction. Having the dispersive power of 13 prisms of heavy flint, each with an angle of 55°, it yet weighs less than 15lb., and measures over all 15in. in length, 8in. in breadth, and 4½in. in height. It was make by Alvan Clark and Sons.

The accompanying plate (Fig. 1), taken from a photograph, gives a correct idea of its appearance and general arrangement. The collimator and observing telescope have each an aperture of ⅞ths of an inch, and a focal length of 7in., which might advantageously have been increased to 12in. were it not for the necessity of compactness.

The light from the slit, after passing the collimator, is transmitted through the lower portion of a train of six prisms of heavy flint glass each 2¼in. high, and having, as stated above, a refracting angle of 55°. A seventh *half-prism* follows, and to the back of this is cemented a right-angled prism, by which, after two total reflections, the light is sent back through the upper part of the same train of prisms, until it reaches the observing-telescope. This is placed directly above the collimator, and firmly attached to it. Finally, a diagonal eye-piece brings the rays to the eye in a convenient position for observation.

The instrument has thus the dispersive power of thirteen prisms, and even with the low magnifying power of only five on the observing telescope, shows perfectly the lines of aqueous vapour, which make their appearance between the sodium lines when the sun is near the horizon. Of course, everything shown on the maps of Kirchhoff and Angström is readily seen with it, and many lines besides.

Its definition is very beautiful, and the only optical fault of the instrument seems to be a curvature of the lines, resulting from the shortness of the collimator.

After planning the instrument, I learned that the same idea of sending the light twice through the prisms by a right-angled

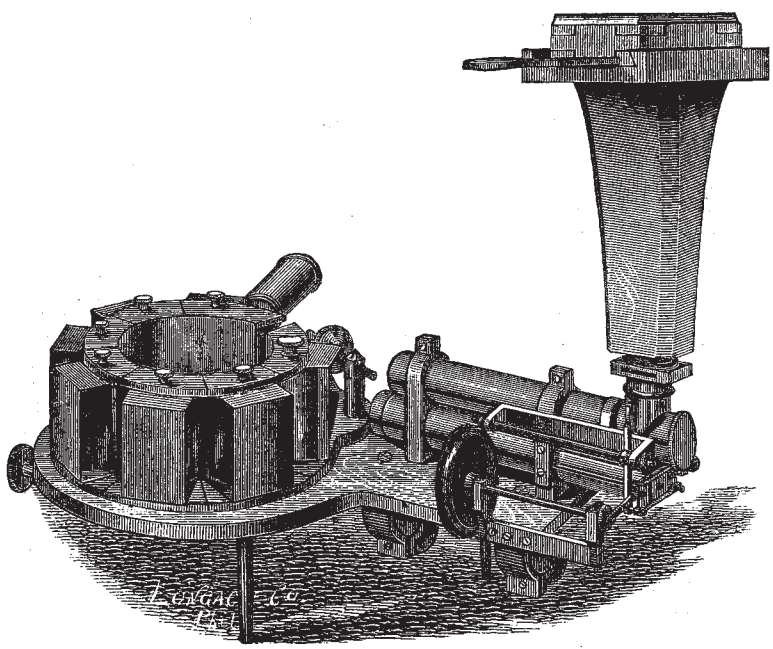

FIG. 1.—A NEW FORM OF SPECTROSCOPE

prism at the end of the train had also occurred to Mr. Lockyer and others; but I do not know that it has yet been put in practice elsewhere.†

The prisms, for protection and convenience of handling, are set in frames of blackened brass. They are arranged around the circumference of a hollow cylinder of elastic gun metal, 3½in. in diameter, with stout flanges above and below, between which they are clamped by little thumb-screws, so that they can be readily removed or transposed: it requires less than a minute to put the last prism with its reflector in place of any other of the train, thus reducing the dispersive power to any extent desired.

No particular care is required in placing the prisms, as a couple of narrow flanges were cast upon the cylinder near the top and bottom, and afterwards planed off to form true bearings for the backs of the prisms. They are thus always correctly set by being simply slid home before tightening the clamping screws.

The lower flange of the cylinder is attached to the base-plate by a screw directly under the middle of the front face of the first prism. Around this point as a centre the whole system of prisms is movable by means of a double-threaded tangent-screw, which brings the different portions of the spectrum into the field of view. The adjustment of the prisms to their angle of minimum deviation is effected by a method devised by Mr. George Clark, which is exceedingly simple, and, if not theoretically exact, answers every practical purpose. The flanges between which the prisms are clamped, are sawed through between the prisms, and a portion of the cylinder, flanges and all, equal to an arc of about 30°, is cut out between the first prism and the last. On closing up or spreading open this gap by means of a suitable tangent-screw, the circumference of the circle around which the prisms stand is correspondingly enlarged or diminished. Probably, when the ends of this opening are drawn very near together, or spread very far apart, the cylinder is somewhat distorted, and a corresponding mal-adjustment of the prisms results; but if so the effect is very slight.

The instrument gives a perfect view of every part of the spectrum from below A to H: above *h*, however, when all seven prisms are used, there is a loss of light occasioned by a partial obstruction of the apertures of the collimator and telescope by the corner of the reflecting prism.

* From the Journal of the Franklin Institute.

† An instrument exactly similar in all essentials to the one here described has been used by Mr. Lockyer for more than a year past.

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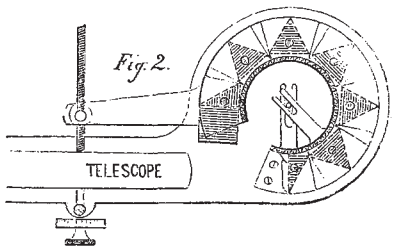
Were it important to secure the perfect cylindricity of the prism-frame through the whole range of adjustment, it could be easily done by merely fastening at the back of each prism a radial bar acting upon a central pin, as in the arrangement first devised by Mr. Rutherfurd, and since adopted by Mr. Browning, in his automatic spectroscope.

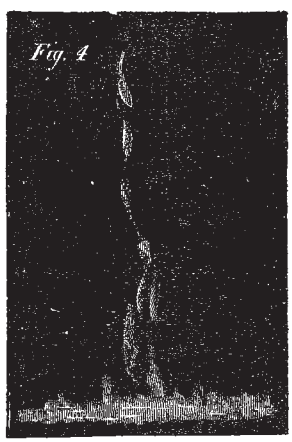
This plan of Mr. Clark's, doing away with all joints and hinges, has the great advantage of perfect firmness and solidity in every



position of the instrument, an advantage hardly to be overrated in an astronomical spectroscope.

Had it occurred to me in season I might have made the instrument still simpler, firmer, and perfectly automatic in its adjustment, by merely substituting for the first prism a half-prism,* like the last of the train, to which the right-angled reflecting prism is cemented.

Placing the first half-prism with its front face perpendicular to the line of collimation, it would never need to be disturbed ; the flange of the cylindrical frame which carries the prisms would be firmly fastened to the bed-plate immediately beneath it, and the pivot joint at this place with the corresponding tangent-screw would be dispensed with. The only adjustment required would be that produced by the screw which is now used to adjust for minimum deviation by opening or closing the gap of the cylinder.



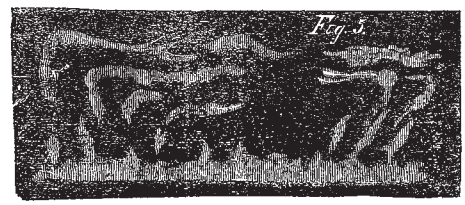
Of course, this arrangement would reduce the dispersive power of the train by the amount of one prism, a loss easily made up by adding a degree or two to their refracting angles.

Fig. 2 exhibits the plan of the proposed arrangement, and requires no explanation, unless to remark that for the sake of distinctness I have represented only two of the radial bars which may be used to render the adjustment accurate.

* On returning from the Eclipse Expedition my instrument will be made automatic in accordance with this plan.

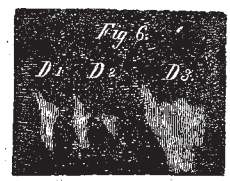
It might be better to place the face of the first prism not exactly normal to the line of collimation, in order to avoid repeated reflections between it and the object-glass of the collimator, which would be likely to produce a troublesome ghost, or the same thing might be accomplished by simply cementing the object-glasses of both collimator and observing telescope directly upon the front of the prism ; this would make the instrument still more solid and compact.

The eye-piece of the instrument has an apparatus attached, which, however, thanks to the high dispersive power, I find unnecessary.

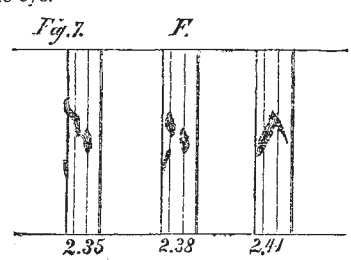


It was early proposed by Janssen to use a vibrating or rotating slit in order to make visible the form of a solar prominence, but as Zöllner has shown, the mere opening of the slit answers just as well, the light of the protuberance being diluted to precisely the same extent in either case.

It occurred to me in connection with a suggestion of Professor Morton, that by interposing at the focus of the eye-piece a diaphragm which should move with the vibrating slit, the light of the neighbouring portions of the spectrum might be cut off and this dilution avoided. Mr. Clark has devised and constructed a very beautiful mechanical arrangement by which this simultaneous and accordant motion of slit and diaphragm is effected by the rotation of the small fly-wheel shown in Fig. 1.



But I find, that although seen in this way, the prominences appear very bright ; yet the working of the apparatus always causes a slight oscillation of the equatorial, which interferes with the definition of details, and I prefer to work with the slit simply opened. When the air is free from haze, the whole extent of a prominence 30,000 miles in height is readily examined through the C or F line, and the most delicate details reveal themselves with a beauty and clearness of definition which even yet always surprises me, and speaks most emphatically for the exquisite workmanship of the 43 different surfaces by which the light is either refracted or reflected on its way from the slit of the collimator to the eye.



But, although I do not use the vibration of the slit and diaphragm, I find the mobility of the slit so convenient as to be practically indispensable. In examining the spectrum of a group of sun-spots, for instance, it is very much easier to move the slit to the particular point we wish to observe, than to move the solar image by the tangent screws of the equatorial.

Photographs of the Solar Protuberances

The protuberances are so well seen through the F and 2796 (near G) lines, that it is even possible to photograph them, though perhaps not so satisfactorily with so small a telescope as the one at my command. Some exp riments I have recently

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made show that the time of exposure, with ordinary portrait collodion, must be nearly four minutes, in order to produce images of a size which would correspond to a picture of the solar disc about 2 in. in diameter. This length of exposure demands a more perfect clockwork than my instrument possesses, and a more accurate adjustment of the polar axis than it had during the experiments, as well as a steadier condition of the atmosphere.

Thus far, therefore, I have not been able to produce anything which could properly be called a good picture. Negatives have been made which show clearly the presence and general form of protuberances, but the definition of details is unsatisfactory. This amount of success was reached upon September 28, when impressions were obtained of two protuberances on the S.E. limb of the sun, and, slight as this success was in itself, I consider it of importance in showing the perfect feasibility of going much further with more sensitive chemicals, more delicate adjustments, and greater telescopic power. I was aided in the experiments by Mr. H. O. Bly, our local photographer, to whom are due my warmest acknowledgments for the interest, patience, ingenuity, and skill with which he assisted me.

We worked through the Hydrogen γ line (2796 of Kirchhoff's scale) which, though very faint to the eye, was found to be decidedly superior to F in actinic power. The photographic apparatus employed consisted merely of a wooden tube, about 6 in. long, attached at one end to the eye-piece of the spectroscope, and at the other carrying a light frame. In this frame was placed a small plate-holder, containing for a sensitive-plate an ordinary microscope slide, 3 in. by 1. The image of the prominence seen through the open slit, is magnified and thrown upon this plate by the eye-piece. Fig. 1 shows the instrument with this apparatus attached.

It would be easy to improve this arrangement in many respects, and whenever I resume the subject I propose to do so.

As the equatorial, however, has been dismounted, to be put in order for the observation of the December eclipse, further attempts in this direction must be postponed until next spring.

Observations of the Solar Protuberances

Without prolonging this article with the detail of observations, I add a few of the results which have been obtained since Sept. 10.

About forty different prominences have been more or less carefully observed; sixteen have been sketched. Most of them fall, naturally enough, into the categories established by Zöllner and Lockyer, and are fairly represented by figures already published in the *Journal of the Franklin Institute*.

A few deserve especial mention, however. Fig. 3 represents a small one which was observed upon the E. limb of the sun, on September 14, about 4.30 P.M. From the point marked A, which was very brilliant, a small fragment detached itself and rose towards A', enlarging in size and growing fainter as it rose. It disappeared (from faintness) in about $12\frac{1}{2}$ minutes, at a distance of 2′ 30″ above the limb of the sun, as determined by the time, 8″·5, which was occupied by the intervening space in passing over the slit of the spectroscope. Allowing for the obliquity of the motion to the parallel of declination, the length of path passed over by this cloud was more than 90,000 miles, and the velocity above 120 miles per second.

Fig. 4 represents a prominence observed September 20, at 4 P.M., on the S.E. limb. (Pos. S., 60° E.) It was a nearly vertical stream, made up of spindle-formed filaments, and had attained the enormous height of 3′ 20″ or 90,000 miles (determined, as in the case above mentioned, by a time-observation, corrected for inclination). It was very brilliant near the base, and at two or three other points along its length. At 4.30 it was nearly gone, only a few faint wisps of cloud remaining.

Another, observed on September 27, at 4.10 P.M., and situated on the W. limb of the sun, is represented in Fig. 5. It was formed of separate, well-defined narrow streamers, which appeared to consist of matter, first violently ejected, and then as violently deflected, by some force acting nearly at right angles. The altitude of the highest point was 1′ 25″, the length of the whole about 3′ 30″. I am unable to see how any mere projection from the sun could have produced such a form, and cannot help feeling that it indicates a something in which powerful currents may exist, even at great elevations above the solar surface; in short, an atmosphere extending far beyond the limits which calculation would seem to assign as possible. Is it wholly unlikely that at such an enormous temperature the law of Mariotte may fail so completely as to destroy the reliability of any computation that assumes it as one of the data?

Upon the next day the prominence still persisted, but its type was wholly changed: it was replaced by one of the mushroom-formed masses which are so common.

Bright Lines

In the spectra of different protuberances, the following bright lines have been observed, the numbers referring to Kirchhoff's scale: C; D_1; D_2; D_3; 1474; 1515; b_1; b_2; b_3; b_4; 1990; 2001; 2031; F; 2581·5; 2796; h—17 in all. On one occasion, September 27, the base of a prominence on the N.W. limb, close to a spot just leaving the limb, exhibited as many as twelve or fifteen short bright lines between E and F, which are not included in the above enumeration, as I had not time to identify them. It is the only instance in which I have seen this phenomenon, more than once described by Mr. Lockyer.

I desire to call special attention to 2581·5, the only one of my list, by the way, which is not given on Mr. Lockyer's. This line, which was conspicuous at the eclipse of 1869, seems to be *always present* in the spectrum of the chromosphere, and shows the form of its upper surface or of a protuberance nearly as well, though of course not so brightly, as the 2796 line. It has no corresponding dark line in the ordinary solar spectrum, and not improbably may be due to the same substance that produces D_3.

The reversal of the sodium and magnesium lines is not at all uncommon. In some instances these lines were so bright that on opening the slit the form of the prominence could be made out through them. This was the case with a small hand-shaped prominence observed on September 27. Comparing the form thus seen through D′ and D_2 with that given by D_3, it appeared that the sodium line was sufficiently developed for observation only along the edge and at one or two bright points in the prominence, most brilliantly neither at its summit nor its base. Fig. 6 represents the appearance (the slit was perpendicular to the sun's limb). The case was similar with the magnesium lines.

Spectrum of Solar Spots

Several spots have been carefully examined at different times; most of them, in their spectra, gave evidence of unusual disturbances; but by far the most interesting phenomena were exhibited by a large group which was first observed near the E. limb on September 19. Changes of wave-length were frequent in its neighbourhood.

Figs. 7 and 8 represent the appearances assumed by the F and C lines respectively, at the times indicated below each figure, during an observation on the afternoon of September 22. The point where these changes of wave-length occurred was at the western edge of the penumbra. At other times similar changes were observed, but not so great or rapidly varying.

The calcium and titanium lines referred to in my note published in the July number of the *Journal of the Franklin Institute*, were always conspicously thickened in the nucleus spectrum.

The C and F lines were reversed in some portion or other of the group nearly every time I observed it. On September 22 the sodium lines were both reversed for several hours, while D_2 appeared as a dark shade. On September 28, again, at 4 P.M., the southern nucleus of the group (which at this time contained four large umbræ, besides many small ones) reversed all of the following lines, viz.: C; D_1; D_2; D_3; 1474; b^1; b_2; b_3; b_4; F; 2796, and h. All of these were conspicuous, except 1474; D_3 and b_3 especially so, and the latter (a nickel line) showed considerable changes of wave-length, alternate increase and diminution, which were not shared by its magnesian neighbours, b^1, b_2 and b_4.

At 4·05 P.M. the brilliance of the F line increased so greatly that it occurred to me to widen the slit, and to my great delight I saw upon the disc of the sun itself a brilliant cloud in all its structure and detail identical with the protuberances around the limb. Indeed, there were *two* of them, and there was no difficulty in tracing out and delineating their form. Fig. 9 represents them as they were from 4·05 to 4·10; Fig. 10 gives the form at 4·15 to 4·20. They were then considerably fainter than at first. During the intervening ten minutes I examined the other lines of the spectrum, and found that the form could be distinctly made out in all the *hydrogen* lines even in h; but that the reversal of the other lines, including D_3, was confined to the region immediately over the spot-nucleus, where the smaller but brighter cloud terminated abruptly; or, I might better say, *originated*. The larger one faded out at both ends. When the clock-work

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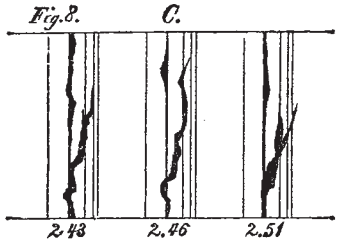
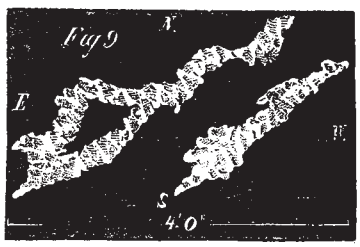
of the equatorial was stopped, the luminous cloud took 16·7 seconds of time to traverse the slit which was placed parallel to the hour-circle. This indicates a length of at least 130,000 miles without allowing anything for the foreshortening resulting from the nearness of the sun's limb.



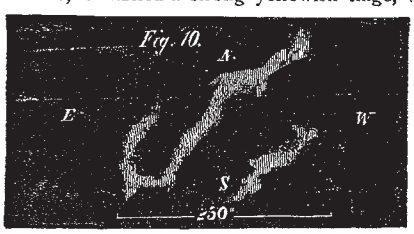
By five o'clock the clouds had nearly disappeared; a little rack alone remained.

At 4.20 I examined the spot with the equatorial, using the ordinary solar eye-piece. Nothing remarkable was to be seen—not the merest trace of the enormous masses of incandescent gas.



It will be interesting to learn whether the earth responded to this magnificent eruption on the sun by any magnetic storm.

I may add that in the telescope this group of spots, from their first appearance, exhibited a strong yellowish tinge, which appeared to overlie all the central portion of the cluster. So conspicuous was it that several persons, unaccustomed to astronomical observation, noticed it at once before I called their attention to it. The penumbra of the group was unusually faint.



Hanover, N.H., October 3 C. A. YOUNG

NOTES

THE first detachment of the Eclipse Expedition for Spain and Algiers started from Portsmouth in H.M.S. *Urgent* on Tuesday morning; the Sicilian party followed overland yesterday evening. An error crept into the names of the party in our list published last week. Professor Roscoe's assistant is Mr. Edward Ernest Bowen, M.A., late Fellow of Trinity College, Cambridge.

AT one of the most recent sittings of the French Institute a communication was made by M. Faye on the intended departure of M. Janssen to join the Eclipse Expedition. This celebrated astronomer was to leave Paris in a balloon constructed for his private use at the expense of the French Government, and which will also carry a telescope, constructed in eight weeks by the most skilful workmen in Paris, and of the capacity of 2,000 cubic metres. It will be fitted up with a new kind of valve, invented by M. de Fonvielle, and which was not quite ready when that gentleman left Paris. According to every probability M. Janssen will ascend with M. Tournier, one of the passengers in the "Pole Nord," but taking the management of the balloon under his own care. The telescope was put in hand a very few days after the 4th of September. The Government appeared so anxious to show the interest taken in the matter that they did not lose a single day after they came into power in fitting up this expedition. The expenses of the construction of the telescope were incurred by the Bureau des Longitudes.

THE French *Académie des Sciences* has held its sittings regularly since the commencement of the siege, and the *Comptes rendus* has been published regularly every week. Every sitting is reported fully, and several numbers have had even more than the average number of pages. A large part of them is devoted to military science and to ballooning. The scheme put forward by M. Dupuy de l'Ome was fully discussed and illustrated by copper-plates: an article contributed to the *Presse*, by Mr. Giffard, the celebrated engineer, when reporting upon his aërial experiments as much as twenty years ago, has been reprinted. It was shown that Dupuy de l'Ome's experiment was almost of the same nature, and the *Académie des Sciences* has apologised for not publishing it in proper time. M. Dumas and M. Elie de Beaumont, although members of the former senate, now act in their capacity of *sécretaires perpetuels* of the Academy. M. Leverrier has not appeared at any of the sittings. M. Chasles is most punctual in his attendance. Lectures are given at the *Conservatoire des Arts et Métiers*, and are to be given at the *College de France*. No lectures have been given this session at the *Sorbonne*. Since the commencement of the siege, a few numbers only have been issued of the *Révue des Cours Scientifiques*; *Les Mondes* and *Cosmos* have been entirely suspended.

A LARGE number of the animals at the *Jardin des Plantes* and *Jardin d'Acclimatation* have been sold and slaughtered for food, even the bears having now been sacrificed. The trees in the latter garden have been almost entirely cut down either for charcoal or for the necessities of the defence.

WE are very glad to be able to report that Sir Roderick Murchison has gained strength during the past week, though his state still continues critical. Prof. Balfour Stewart will have to remain at Harrow for at least some weeks, but is progressing as satisfactorily as possible, considering the nature of his injuries.

THE ratepayers of Marylebone have done good service to Science in electing Miss Garrett, M.D., and Prof. Huxley to the London School Board, first and second on the poll, the former by a triumphant majority over every other candidate. It their example is generally followed throughout the country, we may anticipate great things in the future for the scientific education of the country.

OWING to Professor Tyndall's absence with the Eclipse Expedition, the first conversazione at the London Institution, announced for Dec. 21st, is postponed till Jan. 25th, when he will deliver his lecture on Dust and Disease.

WE regret to learn that the North London Naturalists' Society terminated its existence on Monday, Nov. 27. It has been established for about six years, and was for some time carried on with spirit; but the interest in it has for some time been on the decline, and it was considered advisable to bring it to a close. We understand that it is in contemplation to form another society in its place, which only actual workers will be invited to join. When we consider how many useful bodies of this description are scattered throughout the country, it seems strange that a similar one cannot be kept afloat in London; but the fate of the North London Club, preceded as it was by the collapse of the Society of Amateur Botanists, and of the West End Naturalists'

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